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To: Dr. D. Mills
Director of Research

Digital Protection Signalling

Scope of Work - Research Division

R.C. Madge

Traditional command teleprotection techniques use Frequency Shift Keying with an analogue medium. Newer digital techniques employing optical fibre or other digitally-oriented mediums may increase the reliability and speed of the protection system. A proposed scope of work on digital teleprotection testing is presented. Three phases of possible testing are outlined: insertion of a digital medium; elimination of all analogue components; and development of new protection philosophies. The proposed project will focus primarily on Phase II; the elimination of analogue components. Identification of possible Phase III work is also proposed.

Introduction

Traditional command teleprotection techniques use voice frequency tones over an analogue speech channel. Operation is achieved by switching from a continuous 'guard' frequency to a continuous 'trip' or 'operate' frequency. The quality of these Frequency Shift Keying (FSK) systems is generally determined by reliability and response times.

Over the past several years there have been major breakthroughs in digital communications paths and high speed digital transmission techniques, providing the possibility for faster teleprotection systems with greater reliability. At the request of G.W. Jackson, Manager of Telecommunications Department, a meeting was recently held to discuss possible research activities in digital teleprotection. It was agreed that the Research Division would prepare this document as a starting point for further discussions with the interested parties.

Fibre-optic mediums have incredibly wide bandwidths (1 GHz or greater) giving us the possibility for much greater information transfer. A medium based on fibre optics has other advantages as well. It is impervious to electromagnetic interference and ground potential rise and can span long distances without repeaters. In addition, optical ground wires, or self-supporting all-dielectric cables can be put right on the transmission tower structures. Due to the high bandwidth of optical fibres, protection and control channels, order wires, regular communication circuits and a host of other communication needs can all be accommodated over the same fibre-optic link. If dedicated teleprotection channels are desired, the path data rate will be high enough to provide substantial bit error detection and correction and still provide a very fast response.

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Figure 1 is a block diagram of the traditional FSK command teleprotection technique using an analogue transmission medium. From the relays on, the basic protection signals are in digital form but are converted to analogue form for transmission. When received the analogue signal is converted back to digital.

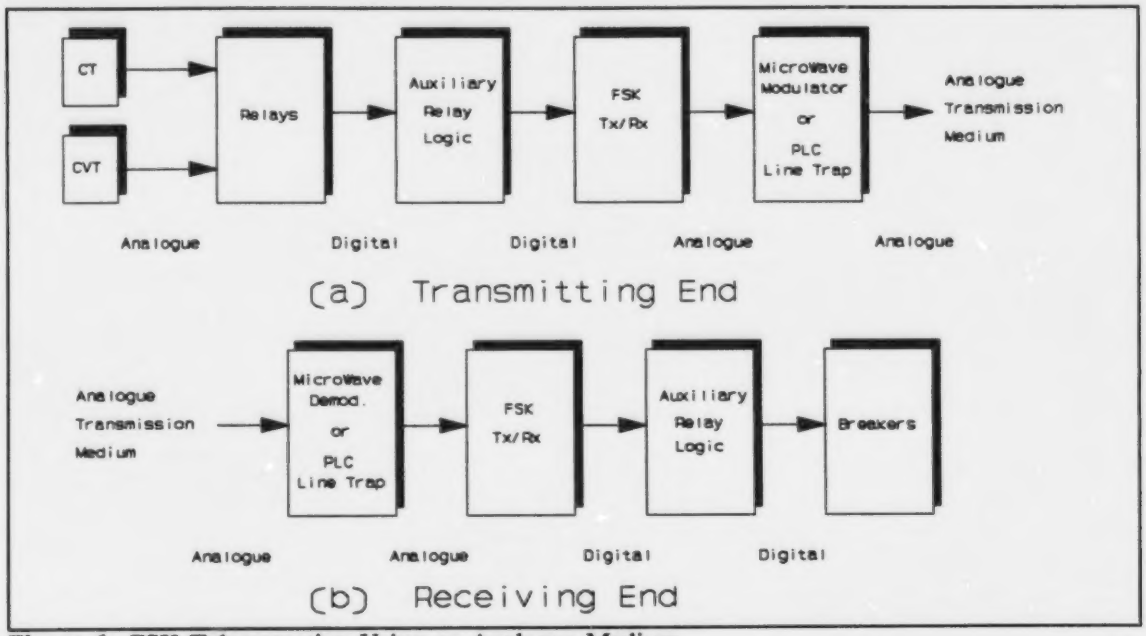

Figure 1 FSK Teleprotection Using an Analogue Medium

With digital communication technology, the complication of conversion to analogue can be eliminated. Implementation of digital techniques should include at least 3 phases:

Phase I — Replacement of the analogue medium with a digital medium.

Alter an existing protection technique to accommodate a digital medium. Test the system to ensure adequate performance during all standard impairments, and also during impairments particular to optical mediums and digital transmission equipment.

Phase II — Elimination of all analogue components in the protection system.

Develop alternatives to traditional command teleprotection philosophies (such as FSK) to more efficiently utilize the digital medium. Equipment more suited to digital environments, such as standard telecommunications equipment (64 kbit/sec) will be necessary.

Phase III — Development of new protection philosophies.

Develop new protection philosophies to better utilize the capabilities of high-bandwidth, interference-immune optical fibres as a communications medium.

Phase I

Phase I testing consists of replacing the analogue medium with a digital one. All the traditional elements of the analogue teleprotection system will be retained with the exception of the modulator (or line traps for PLC) and the medium itself. The FSK signal will be digitized at the transmitting end and reconstructed at the receiving end.

The Telecommunications Department of Design & Development Division - Transmission has already initiated work on Phase I. They will be testing Lenkurt 937B tone equipment used in conjunction with digitizers, multiplexers, demultiplexers and an optical fibre loop. Impairments will include Bit Error Rate fluctuations, optical attenuation increases, changes in clock speeds, loss of optical signal, pulling out cards in the mux/demux equipment, etc.

Figure 2 shows a block diagram of the Phase I test setup. Notice that although the signal is sent digitally across the medium, the signal goes through A/D/A/D at the transmitting end, and D/A/D at the receiving end. This inefficiency should indicate that Phase I is useful only in determining some of the inherent characteristics and limitations of a digital medium.

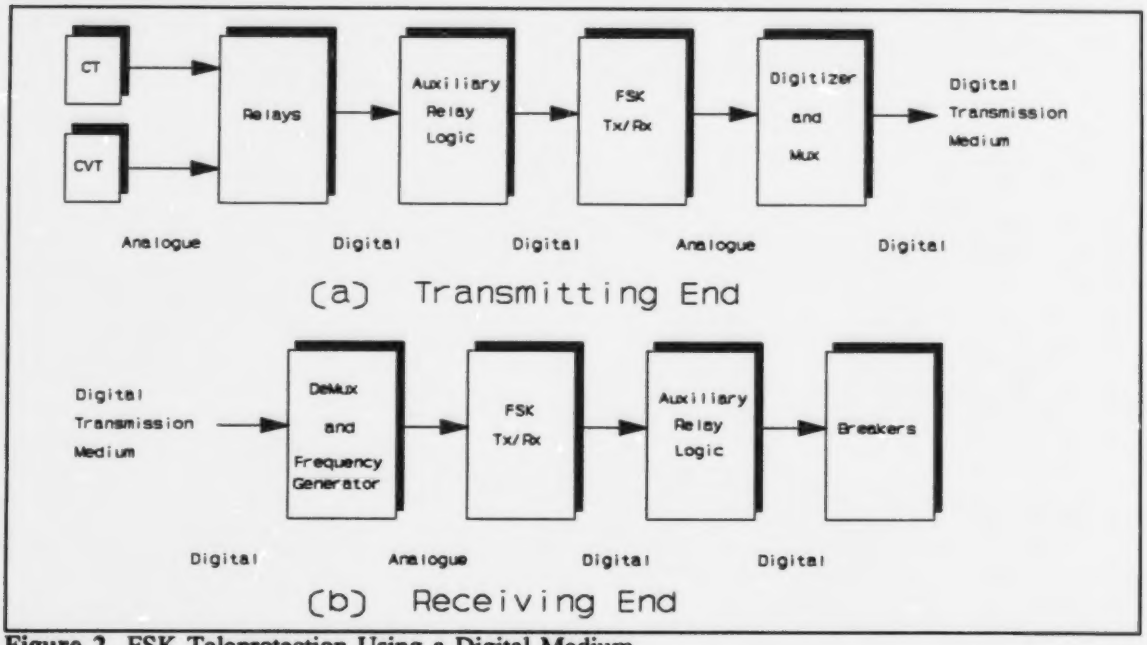

Figure 2 FSK Teleprotection Using a Digital Medium

The involvement of the Research Division in Phase I will be limited to monitoring the activities of the Telecommunications Department, and advising where requested.

Time Frame:	For the duration of Phase I work
Amount of Work:	100 hours
Cost:	$10,000

Phase II

Phase I involves some obvious inefficiencies in the use of equipment and protection techniques. As Figure 2 shows, the signal does a lot of bouncing between digital and analogue. Phase II entails eliminating as much of the intermediate equipment as possible. Figure 3 shows the next logical step. The signal starts as analogue and is converted to digital for signal processing. A digital response is created and sent out on the medium. At the receiving end the digital information is reviewed, and appropriate actions taken. Reliability, speed and cost should improve due to the replacement of some equipment with less complex parts. A further progression would replace the CT, CVT with digital ones making the whole signal processing system digital.

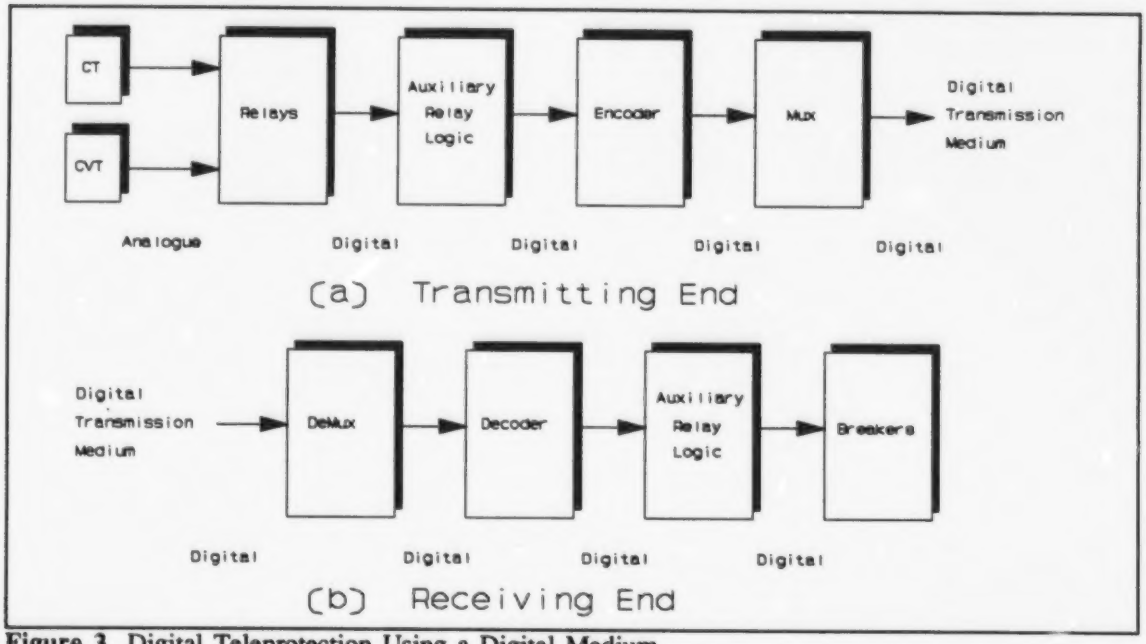

Figure 3 Digital Teleprotection Using a Digital Medium

As a first step in this phase, the literature and existing products will be examined. Where valuable work has already been performed, a minimum of work will be done by us to assure its applicability to our needs. Should existing products turn out to be useful, testing will be performed to assure that product performance is adequate for our needs. Where existing products are deemed to be inadequate for our needs, the first priority will be to work with the manufacturer to redesign the product to produce satisfactory performance.

Only in the event that significant existing work has not been performed, and adequate existing products are not available, and inadequate existing products cannot be reasonably altered to suit our purpose will we move on to the next step: the Research Division will design, implement and fully test one or more protection schemes to send transfer trip commands in an all-digital environment. A detailed report on the reliability and speed under various anticipated conditions will be prepared. As Research will be designing and implementing prototypes, the actual costs of such equipment will have to be estimated.

Testing will include qualitative and quantitative analysis under the following conditions:

- range of additional optical attenuation settings
- application of continuous and/or pulsed noise to the electronic portion of the signal path
- power system voltage variation
- removal and reinsertion of printed circuit board cards
- removal and reinsertion of power from the units
- application of EMI interference (radiated and conducted)
- application of sync loss, overhead frame loss and other digitally-oriented signal problems
- application of interference (tones, continuous noise, pulsed noise) on adjacent channels into multiplexer

Certain equipment necessary to do the testing is not available within the Research Division. This would include multiplexers, demultiplexers, optical attenuators and other pieces necessary to access the optical fibres. We will require access to such equipment for certain periods during the testing phase. A loop back at some point in the system will also be required. Although it is preferred that the testing be performed at Research (optical fibres connected to both Richview SCC and Head Office are already available), it is understood that access to the necessary equipment may dictate the testing location.

Time Frame:	1 to 2 years from initiation of work
Amount of Work:	2000 person-hours
Cost:	$150,000 labour (Equipment will be provided or made available)

Phase III - Definition

To take full advantage of digital techniques for protective relaying, protection systems should be designed from the ground up to integrate the advantages of high bandwidth, interference immunity and high speed inherent in an optical fibre medium. This may entail fundamental changes to our command teleprotection philosophy. Reliance on existing equipment designed for the telecommunications industry may no longer be desired.

Our involvement in Phase III in this project will be limited to the preparation of a detailed Scope of Phase III Work. Some potential new protection techniques may be suggested, such as: transmitting current and voltage information to all stations, and leaving the tripping function up to the individual intelligent terminals; or transmitting load information from all tapped stations to produce dynamic relay characteristics; or eliminating auxiliary relay logic by the combination, within the encoder, of 'words' from various relay outputs.

The Research Division will prepare preliminary concepts including costs and benefits, and put them into a Phase III Scope of Work document. It is anticipated that no work will actually be performed on Phase III concepts in this project.

Time Frame:	3 months from the completion of Phase II
Amount of Work:	200 person-hours
Cost:	$20,000

Summary

Three distinct phases of implementation of digital protection techniques are outlined. Phase I is currently being carried out by the Telecommunications Department of Design & Development Division - Transmission. Research will monitor Phase I and advise where necessary.

Phase II will involve substantial work by the Research Division in a literature and product search, and possibly the designing, implementing and testing of an all-digital protection scheme. A detailed report will be issued.

As outlined in Phase III - Definition, a further scope of work detailing possible Phase III activities will be prepared.

The project as outlined in this scope should take roughly 24 months from initiation of work, and should cost $180,000. This assumes that multiplexing and optical equipment and access to an optical fibre loop will be made available to the Research Division.

Approved:

A.F. Baljet
Manager
Electrical Research Department

Submitted:

Richard C. Madge
Engineer
System Studies Section

RCM:td